REMARKS

Reconsideration and allowance of the subject application are respectfully requested. Claims 1-33 are pending in the present application, claims 1, 18, and 23 being independent. Claims 1, 18, and 23 have been amended.

Allowable Subject Matter

Applicants appreciate the Examiner's indication that claims 4, 5, 7-9, and 33 would be allowable if rewritten in independent form and to include all of the limitations of the base claim and any intervening claim. For the reasons discussed below, Applicants assert that all pending claims are allowable over the prior art of record without amendments.

Abstract Objection

The Examiner has indicated that an abstract is required according to 37 C.F.R. § 1.72(b). Applicants direct the Examiner's attention to the attached Abstract, in accordance with the Examiner's requirement. In view of the above, Applicants respectfully request reconsideration and withdrawal of the outstanding abstract objection.

Disclosure and Drawing Objection

The disclosure has been objected to by the Examiner because of alleged informalities and the drawing, Figure 9, has been objected to because no reference to Figure 9 is contained in the specification. Specifically the Examiner has indicated: that "acquired images are" page 14, line 36 should be replaced; that "the reference" should

be replaced by "acquired images" on page 14, line 37; that "2" should be inserted after "camera" on page 16, line 29; and that "21" should be inserted after "element" on page 16, line 33. Applicants appreciate the Examiner's suggestions and have adopted the last three changes, however the Applicants have replaced "acquired images are" on page 14, line 36 with "the reference image is" as more representative of the intent of the passage.

Additionally in response to the drawing objection the Applicants have inserted discussion concerning Figure 9 into the specification. Applicants believe the inserted discussion contains no new matter, particularly since the discussion of Figure 9 concerns moiré techniques which were first introduced in the specification on page 3, lines 15-26.

In view of the above, applicants respectfully request reconsideration and withdrawal of the outstanding informality objection concerning the disclosure and the drawing objection.

Embodiment Discussion

Before addressing the prior art rejections Applicants respectfully suggest that the Examiner is confusing laser speckle metrology with classical dual-wavefront interferometry. Laser speckle metrology (e.g. electronic speckle pattern interferometry or ESPI) relies on the speckle phenomenon to make measurements. A speckled image is produced when a rough surface is illuminated with coherent (laser) light. In classical interferometry, optically smooth (or approximately smooth) surfaces are employed and thus the speckle effect is absent or significantly reduced. The present invention relates

specifically to classical-type interferometry set-ups where speckle effects are not present or are significantly reduced and thus cannot be exploited for measurement purposes.

The Digital Moiré Subtraction (DMS) technique was developed for interferometer systems based on classical schemes which contain a significant degree of aberration or imperfection. The residual fringe pattern present in the instrument due to these aberrations was actually exploited as a basis for the DMS approach. Although the number/density of residual/carrier fringes can be regulated to some extent by introducing a mirror-tilt, introduction of a tilt is not strictly necessary for the generation of DMS fringes. Also, the specific topology/geometry of the residual fringe pattern is not of great importance in DMS; it is sufficient that the density of the fringes is relatively high. This is a significant advantage since one does not have to generate, for example, a carrier pattern with regular geometry (e.g. evenly spaced parallel fringes) and of a specific spatial frequency/density. The practical consequence of this fact is that adjustment of the interferometer is relatively simple and requires inexpensive fixtures.

Finally, the DMS technique can be applied to any interferometer that produces interference fringe maps as the primary output. Thus the technique is applicable to the measurement of any quantity (e.g. displacement, shape, refractive index, temperature ...) that results in a change in optical path length within the interferometer, producing a fringe image or interferogram. The DMS method as presented, therefore, is not application specific.

Prior Art Rejections

1. Rejection under 35 U.S.C. § 103 (a) based on Lulli in view of Duffy

Claims 1, 3, 6, and 10-32 stand rejected under 35 U.S.C. § 103(a) as being unpatentable over Lulli et al. (U.S. Patent No. 5,870,196) in view of Duffy (U.S. Patent No. 3,767,308). This rejection is respectfully traversed.

The Examiner has indicated (Office Action, page 3) that Lulli in view of Duffy would have allegedly made the invention defined by claims 1, 3, 6, and 10-32 obvious to one of ordinary skill in the. In actuality neither Lulli nor Duffy discuss non-speckle based systems.

Lulli effectively describes a speckle-based optical coherence tomography/topography (OCT) system (Abstract; "three-dimensional profile," col. 1, ll. 37). OCT systems are a completely different class of optical metrology system since their operational principle is fundamentally different from classical interferometry. Central to OCT systems is the necessity to use low-coherence light (col. 1, ll. 42) (i.e. light with a large optical bandwidth, not laser light).

Duffy is based on the imaging of a speckle pattern generated by illuminating an object with coherent light (col. 2, ll. 20-23).

Independent claims 1, 18, and 23 are directed to measurement apparatuses and methods that use non-speckle interference patterns. Lulli and Duffy use speckle-based systems. Thus, Applicants fail to see how two references specifying the use of speckle-based systems can motivate one of ordinary skill in the arts to construct the non-speckle based device or methods of claims 1, 18, and 23.

To establish a *prima facie* case obviousness under 35 U.S.C. § 103, the Examiner has the burden of meeting the following three basic criteria: (1) the prior art must teach or suggest all of the claim limitations; (2) there must be a reasonable expectation of success; and (3) there must be some suggestion or motivation, either in the art or knowledge generally available to one of ordinary skill in the art to modify the reference or to combine teachings (M.P.E.P. § 2143)(emphasis added).

Regarding the third basic criteria, if a proposed modification of the primary reference would render the device being modified unsatisfactory for the reference's intended purpose, then there is no suggestion or motivation to make the proposed modification (M.P.E.P. § 2143.01). The use of hindsight to reconstruct the claimed invention is clearly impermissible. Uniroyal Inc. v. Rudlan-Wiley Corp., 5 U.S.P.Q.2d 1434 (Fed. Cir. 1983).

Therefore, Applicants respectfully submit that the Examiner has not satisfied the *prima facie* requirement of showing a teaching or suggesting of all of the claimed limitations defined by independent claims 1, 18, and 23 which describe a non-speckle based invention for the reasons discussed above.

Applicant has already explained why Lulli in view of Duffy fails to teach or suggest the invention of independent claims 1, 18, and 23. Since claims 3, 6, 10-32 each depend, either directly or indirectly, from claims 1, 18, and 23, claims 3, 6, 10-32 are allowable at least for the reasons generally expressed above with respect to claims 1, 18, and 23.

In view of the above, Applicants respectfully request reconsideration and withdrawal of the outstanding rejection of claims 1, 3, 6, and 10-32 under 35 U.S.C § 103(a).

2. Rejection under 35 U.S.C. § 103 (a) based on Lulli + Duffy + Noguchi

Claims 1, 3, 6, and 10-32 stand rejected under 35 U.S.C. § 103(a) as being unpatentable over Lulli + Duffy further in view of Noguchi et al. (U.S. Patent No. 5,432,606). This rejection is respectfully traversed.

The Examiner uses Noguchi to allegedly show the tilting of a reflecting surface to increase the number of interference fringes in the first interference fringe pattern (Office Action, page 4). Noguchi specifically uses the interference fringes containing a spatial carrier, due to the tilt of a surface, to accurately measure the displacement of a reference mirror (col. 1, ll. 13-15; col. 2, ll. 34-38). Noguchi's method is associated with optimum alignment of a classical interferometer rather than a technique to make measurements. The method relies on the use of an aberration-free interferometer and thus there is no provision for imperfections that might be present in the instrument.

Applicants fail to see how the alignment system of Noguchi would motivate one of ordinary skill to utilize the alignment technique of Noguchi for classical interferometers in the speckle-based systems of Lulli and Duffy to allegedly derive the measurement method of claim 2, which is directed to a non-speckle-based method. Claim 2, being dependent on claim 1, is also directed to a non-speckle based method.

Applicant has already explained why Lulli in view of Duffy fails to teach or suggest the invention of independent claims 1. Since claim 2 depends from claim 1 and Noguchi fails to supply the missing elements of Lulli and Duffy, claim 2 is allowable at least for the reasons generally expressed above with respect to claim 1.

In view of the above, Applicants respectfully request reconsideration and withdrawal of the outstanding rejection of claim 2 under 35 U.S.C § 103(a).

Conclusion

In view of the above amendments and remarks, Applicants respectfully request reconsideration and withdrawal of the formal objections and rejections to the claims, and the rejections based on prior art. Because all claims are believed to define over prior art of record, Applicants respectfully request an early indication of allowability.

If the Examiner has any questions concerning this application, the Examiner is requested to contact the undersigned at (703) 205-8000 in the Washington, D.C. area.

Pursuant to 37 C.F.R. §§ 1.17 and 1.136(a), Applicants respectfully petition for a one (1) month extension of time for filing a reply in connection with the present application, and the required fee of $110.00 is attached hereto.

If necessary, the Commissioner is hereby authorized in this, concurrent, and future replies, to charge payment or credit any overpayments to Deposit Account No. 02-2448 for any additional fees required under 37 C.F.R. §§1.16 or 1.17; particularly, extension of time fees.

Respectfully submitted,

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MARKED UP VERSION TO SHOW CHANGES MADE

IN THE SPECIFICATION:

Please amend the specification as follows:

Page 14

Please replace the paragraph beginning at line 26 with the following rewritten paragraph:

--A method in accordance with a preferred embodiment of the present invention includes a process which shall be referred to as Digital moiré subtraction (DMS). The interferometer is configured with a means of introducing carrier, or tilt fringes in the interferogram, with the number of fringes across the field variable, but within the resolution of the image camera and frame store. This can usually be accomplished by manual adjustment of a mirror. The image is captured, digitally stored and used as a reference. Subsequently [acquired images are] the reference image is then subtracted from the [reference] acquired images and the difference displayed.--

Page 16

Please replace the paragraph beginning at line 24, ending on page 17, line 15, with the following rewritten paragraph:

--Illumination is provided by a He-Ne laser, 9 fitted with a diverging objective at a distance approximating to the focal length of the interferometer collimating lens (L1). The second lens, at the exit of the system acts as a field lens for the CCD camera 2 used to capture and record the interferograms. The apparatus is arranged such that the patterns of the interference fringes produced by the interferometer 1 are [focussed]

focused onto the CCD sensing element 21 of the camera. The camera outputs a continuous stream of captured digital images I(t) and an image store 3 is arranged to record an image captured at a selected time. The apparatus includes an image recorder arranged to record the sequence of captured images, which can also play the images back to the image processor 4. The image processor 4 combines the stored image $I(t_1)$ with the live image or image retrieved from the recorder 7 to produce a further image FI including a moiré fringe pattern. The further images are displayed on a display 5 in real time (at video rate) and/or may be recorded by the, or another, recorder 6. Briefly, the mechanism for generating interference fringes is by interference between the two reflected beams from M1 and M2, which are added by BS. Any perturbation of one beam resulting from the insertion of an optical component, or refractive index variation caused, for example, by convective flow, will disturb the wavefront of this beam and produce interference fringes.--

Page 17

Please replace the paragraph beginning at line 27 with the following rewritten paragraph:

--A tilt was applied to one mirror in order to produce an even finer pattern, largely free from broadly spaced fringes. In a method embodying the present invention, this image is captured and then digitally subtracted from the live image. The optical errors in the interferometer are thus removed making it [is] sensitive only to the errors of the introduced test component. As a test, by introducing an additional small tilt (i.e. a tilt in addition to the tilt applied to produce the even finer pattern) to one mirror the subtracted

moiré interferogram of Figure 2(b) was produced. Such straight and uniformly spaced moiré fringes 12 are normally expected only from an interferometer possessing a high degree of optical correction.--

Page 21

Please replace the paragraph beginning on line 27 and ending on page 22, line 9, with the following *three* paragraphs:

--In testing components that are subject to high levels of strain, hundreds of interference fringes may be generated and whose orientations vary greatly. This will present problems in applying successfully automatic fringe analysis by the traditional approach. With DMS, the test interferogram of the high strain condition can be stored as a new reference, i.e. a "snapshot" of the interference fringe pattern can be taken at a particular moment in time, for use as a reference image. The interferometer is then reset to a null fringe condition, so that subsequent changes in the level of strain will appear as individual moiré fringes, rather than a subtle variation to a complex pattern. This process has important implications in the enhanced detection of special events in testing, such as the [intiation] initiation of cracking and the onset of plastic deformation.

A feature of moiré techniques applied to in-plane displacement measurement is a method for displaying in-plane strain contours by shearing the image upon itself. In moiré interferometry this could be applied by performing a subtraction between two sheared interferograms, both at the same high strain state. The shear can be introduced digitally and with little delay, so that the potential for displaying strain contours in effectively real time is possible. Figure 9 is an example of an x-strain contour map of an

aluminium test specimen containing a crack. The contours show interference fringes 11 and moiré fringes 11, as discussed above. The strain intervals are approximately 0.05% strain.

In testing components which bear an imperfect surface pattern, due to errors in pitch or local orientation, the imperfections can be eliminated along with the other optical aberrations.--

Page 23

Please replace the paragraph beginning at line 10 with the following rewritten paragraph:

--Apart from the facility for [ameliorting] ameliorating the effects of gross aberrations of the optical components, another advantageous feature of digital moiré subtracting is its potential in large aperture interferometry. In a preliminary study, an interferometer based on the Fizeau design was constructed from simple components.--

Please replace the paragraph beginning at line 17 with the following rewritten paragraph:

--Figure 5[,] indicates that two nominally flat and parallel glass sheets (P1, P2) and a collimating lens can be used to demonstrate the principle of the approach. Interference takes place between the wavefronts reflected from the rear surface of P1 and the front surface of P2. The combined wavefronts are [re-focussed] re-focused by the collimating lens and directed towards the CCD camera 2 via the beam-splitting glass plate P3. All the components are uncoated; hence the intensity of the emergent

captured light is low, restricted by the combined reflections of approximately 4% at each interface of P1, P2 and P3. In addition, the contrast of the interferograms and the subsequent moiré image were reduced because of the limited coherence length of the [HE-Ne] He-Ne laser and the dissimilar optical paths. A gap of approximately 100mm between P1 and P2 caused a marginal degradation of fringe contrast.--

IN THE CLAIMS:

The claims have been amended as follows:

1. (Amended) A measurement method comprising the steps of:

arranging an interferometer to form a non-speckle first interference fringe pattern comprising at least ten interference fringes;

recording an image of said first interference fringe pattern;

perturbing an optical path in the interferometer to form a non-speckle second interference fringe pattern comprising at least ten interference fringes; and

combining an image of said second interference fringe pattern with the recorded image of the first interference fringe pattern to produce a further image comprising a moiré fringe pattern arising from a difference or differences between the first and second interference fringe patterns.

18. (Amended) A measurement method comprising the steps of:

arranging an interferometer to form a[n] non-speckle interference fringe pattern comprising at least ten interference fringes;

perturbing an optical path in the interferometer to alter the interference fringe pattern;

combining the recorded image with each one of a sequence of images of the interference fringe pattern at respective different times to produce a sequence of respective further images each comprising a moiré fringe pattern arising from a difference between the recorded image and the respective one of the sequence of images.

23. (Amended) Measurement apparatus comprising:

an interferometer arranged to form non-speckle interference fringe patterns comprising at least ten interference fringes;

a camera arranged to capture images of the interference fringe patterns;

an image store arranged to store an image of the interference fringe pattern captured by the camera at a selected time;

an image processor arranged to combine the stored image with an image of the interference fringe pattern captured by the camera at a different time to produce a further image comprising a moiré fringe pattern arising from a difference or differences between the interference fringe patterns at the selected and said different time.